The Optimal Protection and Pricing for Software Products in the Presence of Network Externalities

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ABSTRACT

Piracy has been claimed to be the major problem of software sales. It is traditionally believed that piracy will have negative effects on the revenue of software producers. However, in the presence of network externalities, piracy enlarges the user base, and thus will increase the value of the software, which is a positive effect to producers. This paper investigates the optimal protection level and pricing policy in the presence of network externalities. We found that (1) optimal price should be greater than marginal cost, (2) the optimal protection depends on net network effect and marginal cost, and (3) the effects of price change to total revenue is related to the demand elasticity and net network effect.

Keywords: Network Externality, Software Piracy, Pricing

1. INTRODUCTION

Private copying is claimed to be a major problem for the microcomputer software industry since consumers can obtain copies with the same quality of the original at low cost. The consumers who pirate would not buy the originals. Therefore, intuitively, software piracy corrodes the sales as well as the profits of the firm. However, there exists another effect when people pirate software. Though piracy reduces the retail demand for the original software, it increases the total number of the software users, i.e., the installed base of the software is larger. Consumers' willingness to pay for the software would be higher and the demand for the software thus increases when the software presents significant positive consumption or network externalities.

The positive network externality describes the situation in which the consumers' utility for a product increases with the number of other persons who are using the same product. Increasing protection of a product will raise the costs of pirating. It therefore causes some who would pirate to buy originals and leave others to abandon the product. That is, those who decide not to use the product represent a reduction in the network size. With the existence of positive network externalities, the smaller installed base leads to a lower value of the software product and may also reduce the producers' profits. This paper attempts to derive the

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conditions for firms to choose the optimal protection level and price in the presence of network externalities.

Network externality is first defined as a product for which the utility that a user derives from consumption of the good increases with the number of other agents consuming the good (Katz and Shapiro [4], [5]). In the example of computer software, an agent purchasing a computer software would consider how many agents are using the same software. The consumers will take the interchangeability of files into account. The benefit of use will increase with the number of persons who use the same program because the files can be exchanged and shared among users. On the other hand, users that use the same software can also be benefited by the availability of experience-sharing. That is, it is much easier to find sources of information on using the dominant program when the software program is popular in use. To sum up, in the presence of network externalities, a software firm must balance the opposite effects of increasing the protection level on the sales to maximize the profits. It is interesting to investigate the optimal protection level of a software product in business practice when the software exhibits significant network externalities.

The organization of this paper goes as follow. Some relevant literature are review in Section 2. Section 3 establishes the model of a software firm which considers the protection of its product in the presence of network externalities. The results derived from the model are discussion in Section 4.

2. LITERATURE REVIEW

A number of recent articles have provided the effects of private copying on producer and consumer welfare. Some of them didn't take network externalities into account when measuring the effects of copying on welfare. Liebowitz [6] concerned exclusively with photocopying of journals and concluded that total welfare, consumer surplus plus producer profit, always increase as a result of copying if there are no cost associated with the functioning of such market. His analysis didn't pertain the software market because of the crucial assumption he made that pirate copies can only be reproduced from originals. As a result, it is possible for producers to appropriate some of the consumer gains from illegal copies. Besen [1] and Besen and Kirby [2] found that the effects of piracy on consumer and producer welfare depend on the assumptions made about the substitutability between originals and copies and on the relative costs of producing originals and copies. The cheaper copies can be substituted for more expensive originals, both producers and consumers are better off. If both are relatively inexpensive to produce, then, in general, producers lose and consumers gain. Takeyama [8] concludes when demand network externalities are considered, not only can illegal copying lead to greater firm profits, it can produce a Pareto improvement in social welfare. This implies that standard measures of the harm to producers and society from unauthorized reproduction of intellectual property may be overstated. Takeyama [8] also found that the net effect of piracy—and whether the producer can be better off by not protecting—depends on balancing piracy's value-enhancing effect against the sales loss caused by piracy.
3. THE MODEL

There are some assumptions made in the model. At first, immediate response is assumed for the static analysis. The consumers will pirate if the difference between willingness to pay and market price is less than that between willingness to pay and copy cost. That is, if \( N(P) > V_i(N) - c_i \), where \( c_i \) is the cost of copying depending on the protection technology, then the consumer will pirate rather than purchase the original. Similarly, if the excess willingness to pay for purchasing is higher than that for copying, the consumer will be the user of original, i.e., \( N(P) > V_i(N) - c_i \).

Assume that there are \( N^h \) consumers buying product and \( N^l \) consumers pirate. The total number of consumers adopting the product is \( N^h + N^l \). The presence of network externalities means that there are demand-side economies of scale. That is, \( V_i(N) > V_i(N_1) \) \( \forall i \) whenever \( N_i > N_{i-1} \), where \( V_i \) is the valuation function of consumers, i.e. willingness to pay. \( N \) is the total number of consumers from both groups who adopt the computer software. Consumers' valuation of the product increases in the number of other consumers who consume the same software program.

Furthermore, assume \( \delta \) is the software protection technology index to prevent piracy, and the larger \( \delta \) is, the higher level the protection technology is. It is assumed that the costs of cracking protected software is fixed. After the software is cracked, the users are indifferent by using the originally protected or cracked version of the same program. When the excess willingness to pay for a copy becomes less than that for an original, an individual will choose to purchase original. When a consumer excess willingness to pay for an original or a copy is negative, i.e., \( V_i(N) - P < 0 \) \( V_i(N) - c_i < 0 \), he exits the market. Therefore, an increasing protection might cause a decrease in the number of piracies as well as in network size. Formally, the assumptions about protection technology are as follows:

\[
\frac{\partial N^h}{\partial \delta} > 0, \quad \frac{\partial N^l}{\partial \delta} < 0
\]

On the supply side, we assume that the software program in discussion is produced by a profit-maximizing monopolist, whose production cost function is a function of quantity and protection technology. The total profit function of the monopoly firm is:

\[
(1) \quad \Pi = P \cdot D(V(N^h + N^l), P) - C(D(N^h + N^l), P, \delta)
\]

where

\[
N^h = N^h(V_i, P, c_i(\delta)) \\
N^l = N^l(V_i, P, c_i(\delta))
\]

where \( C \) is cost function of producing software program and \( c_i \) is piracy cost. \( N^h + N^l = N \) is the network size and \( P \) is the market price. Due to positive network externalities, the consumer valuation of software program depends on the size of network. And we assume that a consumer purchases only a single unit of the program; no additional value can be obtained from additional units. This assumption is reasonable in software market, since users won't install more than one same program in a personal computer at a time. The demanded quantity of the product depends on the willingness to pay and the market price. The higher excess willingness to pay,
the more demand quantity. The effect of price change on the number of originals and piracies is different. The higher the price, the less consumers will buy it. Some consumers might change their mind from purchasing originals to pirating. As a result, the number of piracy will increase if the monopolist increase price. But those who do without the product won't become piracy. That is the increase in pirating due to price increase is from the group in which consumers choose to purchase original. The total network size doesn't change. There are asymmetric effects when price decreases, because some individuals who do without the software program initially might enter the market to pirate or purchase. Some of those who pirate might purchase. That is, the network size enlarges when the price reduced. From the assumptions above, we conclude that:

\[
\frac{\partial D}{\partial V} > 0, \quad \frac{\partial C}{\partial D} > 0, \quad \frac{\partial N^b}{\partial P} < 0, \\
\frac{\partial V}{\partial N^i} > 0, \quad i = h, l \\
\frac{\partial C}{\partial \delta} > 0, \quad \frac{\partial N^i}{\partial \delta} < 0, \quad \frac{\partial N^h}{\partial \delta} > 0
\]

The first order necessary conditions for profit-maximizing are:

\[
\frac{\partial \Pi}{\partial \delta} = P \left[ \frac{\partial D}{\partial V} \frac{\partial v}{\partial N^b} \frac{\partial N^h}{\partial \delta} + \frac{\partial D}{\partial V} \frac{\partial N^i}{\partial \delta} \right] \\
- \left[ \frac{\partial C}{\partial D} \left( \frac{\partial D}{\partial V} \frac{\partial v}{\partial N^b} \frac{\partial N^h}{\partial \delta} \frac{\partial N^i}{\partial \delta} \right) + \frac{\partial C}{\partial \delta} \right] = 0
\]

\[
\frac{\partial \Pi}{\partial P} = D(,) + P \left[ \frac{\partial D}{\partial V} \left( \frac{\partial v}{\partial N^b} \frac{\partial N^h}{\partial P} + \frac{\partial v}{\partial N^i} \frac{\partial N^i}{\partial P} \right) \right] \\
- \left[ \frac{\partial C}{\partial D} \frac{\partial D}{\partial V} \left( \frac{\partial v}{\partial N^b} \frac{\partial N^h}{\partial P} + \frac{\partial v}{\partial N^i} \frac{\partial N^i}{\partial P} \right) \right] = 0
\]

The interpretation of equation (2) goes as follows. The first term in first bracket, i.e., \( \frac{\partial D}{\partial V} \frac{\partial v}{\partial N^b} \frac{\partial N^h}{\partial \delta} \), is the effect of increasing protection on demand quantity. It occurs when the protection causes some pirates to purchase original. This is a positive effect on the total profit. The second term in the first bracket is the marginal loss of copyright protection on total revenue due to a reduction in network size. The summation of these two terms are the net effect of network externalities. If the net effect of network caused by protection is negative, then \( \frac{\partial TR}{\partial \delta} < 0 \). It means that an increase in protection technology will lead to less total revenue. The effect of protection on cost is divided into two parts. One is positive demand effect, the other is negative. The first term in the second bracket states the marginal cost of protection technology due to network externalities. This will be negative if the net network effect is negative. It means a decrease in demand because of declining illegal users has larger effect on cost than a increase in demand because of increasing legal users. The term,
\( \frac{\partial C}{\partial \delta} \)

is the marginal cost of adopting protection technology itself, and this term is positive. Equation (2) is the condition for choosing optimal protection. We could easily see from (2) that the optimal protection depends on the net network effect due to protection change and the marginal cost of developing new protection technology.

We could get other interpretations by rearranging equation (2) into (4).

\[
(4) \quad (P - \frac{\partial C}{\partial D}) \cdot \left( \frac{\partial D}{\partial V} \cdot \frac{\partial N^h}{\partial \delta} + \frac{\partial D}{\partial V} \cdot \frac{\partial N^l}{\partial \delta} \right) = \frac{\partial C}{\partial \delta}
\]

or

\[
(4') \quad (P - \frac{\partial C}{\partial D}) \cdot (\text{Net Network effect of Protection}) = \frac{\partial C}{\partial \delta}
\]

Since the right hand-side of (4) is positive, \( P - \frac{\partial C}{\partial D} \) has the same sign with the net network effect. It means, with the negative net network effect of protection, a monopolist will set a price less than the marginal cost. This result derived is different from the conclusion discussed in traditional monopoly literature, in which the price is a markup over marginal cost, with the amount of markup depends on the elasticity of demand.

Equation (3) could be interpreted as follows.

The first two terms express the change of total revenue due to change in price. The sign of \( \frac{\partial TR}{\partial P} \) is ambiguous. Rearrange the first two terms of (3) to (5):

\[
(5) \quad \frac{\partial TR}{\partial P} = D(\cdot) + P \cdot \frac{\partial D}{\partial P} + P \left( \frac{\partial D}{\partial V} \cdot \frac{\partial N^h}{\partial P} + \frac{\partial D}{\partial V} \cdot \frac{\partial N^l}{\partial P} \right)
\]

or

\[
(5') \quad \frac{\partial TR}{\partial P} = D(\cdot) + P \cdot \frac{\partial D}{\partial P} + P \cdot (\text{Net Network effect of Price Change})
\]

Net network effect of an increase in price includes two terms. One is \( \frac{\partial D}{\partial V} \cdot \frac{\partial N^h}{\partial P} \).

This is a negative effect which caused by the reduction of legal users. The other is \( \frac{\partial D}{\partial V} \cdot \frac{\partial N^l}{\partial P} \) would be zero, since a individual once chooses to pirate, he will still decide to pirate when price increase. But if price reduces, there might be some pirates who become legal users, the total revenue of the firm increases. Besides, some individuals neither purchase nor copy might enter the network. Hence, the network size become larger when the firm charges lower price.
Compared with the traditional analysis\(^1\) of monopoly firms,
\[
(6) \quad \frac{\partial TR}{\partial P} = D(.) + P \cdot \frac{\partial D}{\partial P}
\]
The difference between (6) and (5) is that we have an additional net network effect term, which reflects the network effect on total revenue when price changes. Taking network externalities into account, total revenue change due to price increase won't be as much as the conventional result. But when price decreases, the total revenue will change more than the model without network externality. The third term of equation (3) is the cost change caused by price change which effects demand quantity through network externalities. Given the assumptions discussed above, this term is negative.

We could get some other interpretation by rearranging equation (3).

\[
(6) \quad D(.) \cdot (1 - |\varepsilon_d|) + (P - \frac{\partial C}{\partial P})
\]
\[
\left( \frac{\partial D}{\partial V} \cdot \frac{\partial V}{\partial N^b} + \frac{\partial D}{\partial V} \cdot \frac{\partial V}{\partial N^b} \cdot \frac{\partial N^b}{\partial P} \right) = 0,
\]
where \( \varepsilon_d = \frac{\partial D}{\partial P} \cdot \frac{P}{P} \) is price elasticity of demand.

Since the sign of \( (P - \frac{\partial C}{\partial D}) \) is ambiguous, and
\[
\left( \frac{\partial D}{\partial V} \cdot \frac{\partial V}{\partial N^b} \cdot \frac{\partial N^b}{\partial P} + \frac{\partial D}{\partial V} \cdot \frac{\partial V}{\partial N^b} \cdot \frac{\partial N^b}{\partial P} \right)
\]
is negative, whether the firm produce at the circumstance of \( |\varepsilon_d| \) or not\(^2\) depends on the sign of \( (P - \frac{\partial C}{\partial D}) \). If price is less than marginal cost, at the optimal price, the elasticity of demand must be greater than one and vice versa. The equation (3) is the condition for the firm to set up the optimal price. However, a monopoly firm has to investigate the effects of the network externalities of its product.

4. CONCLUSIONS

The key feature of this paper is to investigate the pricing strategy and optimal protection level for a software firm. The conditions for choosing optimal protection and pricing policy differ from the traditional results when taking network effect into account. The main reason is when the monopolist increases protection on software to prevent pirates, the number of private copying will reduce, so does the network size. The smaller the network size is, the less consumer's willingness to pay will be.

The model studied in this paper shed some lights on business policies of pricing and protection for software products. The results are summarized as follows:

\( D(.) \cdot (1 - |\varepsilon_d|) = - \left[ \left( \frac{\partial D}{\partial V} \cdot \frac{\partial V}{\partial N^b} \cdot \frac{\partial N^b}{\partial P} + \frac{\partial D}{\partial V} \cdot \frac{\partial V}{\partial N^b} \cdot \frac{\partial N^b}{\partial P} \right) \cdot (P - \frac{\partial C}{\partial D}) \right] < 0 \) if \( P - \frac{\partial C}{\partial D} < 0 \), therefore \( |\varepsilon_d| > \).

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\(^1\)If
\( TR = P \cdot D(P), \)
\( \therefore \frac{\partial TR}{\partial P} = D(.) + P \cdot \frac{\partial D}{\partial P} \)

\(^2\)The conditions for choosing optimal protection and pricing policy differ from the traditional results when taking network effect into account.
1. Optimal price should be larger than marginal cost if there is a positive net network effect. That is, when there are more consumers transferring from pirates to buyers than exiting from pirates to doing without, monopoly firm will charge a higher price (higher than the marginal costs). Otherwise, the software producer will charge a lower price, if the reduction in illegal users does diminish the network size.

2. Optimal protection is determined by equation (4). Obviously, the optimal protection depends on net network effect and marginal costs. Regarding the effect of protection on total revenue, if increasing protection causes a decrease in network size, then the total revenue will reduce. That is, firm has to survey the protection impact on network size to determine the optimal protection. Without taking network externalities into consideration, the protection level is not optimal and will be overstated.

3. The influence of price change on total revenue now depends not only on the demand elasticity but also on the net network effect. A point worth noticing is that there is asymmetric effects when the price increases and reduces. When the firm reduces price, the network effect is larger than that of price reduction.

There are still a lot of avenues through which this model could be extended. One is the dynamics of the network effect. Here in this paper, we assume immediate response and perfect foresight by all consumers. Besides, we didn't consider the substitutability between originals and pirates. If there exists imperfect substitution, the result would be a little different. Another possible extension is to apply competitive dynamics in a multi-firm setting. The optimal degree of protection employed will be a critical element of a software firm's competitive strategy. Firms could benefit from the network effects of piracy with the optimal protection.
REFERENCES:


